STAGED COAL GASIFIER FOR POWER GENERATION AND FUEL PRODUCTION

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ABSTRACT

As coal is the most abundant fossil fuel, coal should be used for not only power generation but also production of fuel and agriculture chemicals. Staged coal gasifier can increase production of methane by controlling the feed oxidizer ratio between stages. The gasifier can also control the ratio hydrogen and carbon monoxide by feed steam to secondary stage. The gasifier can product di-methyl ether easily at hydrogen production equal to carbon monoxide. The 50 tons per day pilot plant of the gasifier tested at Chiba prefecture in Japan from 1990 to 1995 by NEDO (The New Energy and Industrial Technology Development Organization). The main objective is production of Hydrogen. The new 150 tons per day pilot plant has started construction from 1998 by Electric Power Development Co., LTD. EAGLE (Coal Energy Application for Gas Liquid and Electricity) project aims to increase efficiency of staged gasifer and to achieve high performance clean up system.

INTRODUCTION

Coal is the most abundant of the fossil fuels. At the end of 1990, proven world reserves of coal were estimated to be sufficient for more than 200 years at 1990 production rates. Its wide geographical distribution ensures that coal is to be found in every continent, and is fossil fuel in many countries.

Most coal used in power station. Coal-fired power stations generated almost 40% of the world's electricity. As coal is likely to remain a primary energy resource for the future environment concerns continue to dominate, these aspects will determine which technologies will be employed to convert coal in power. Therefore, that a great deal of effort is being directed into reducing the environmental impact of coal-fired generation through the environment of clean coal technologies.

Gasification processes produced fuel gas, which can be cleaned prior to firing in the turbine combustor, and suffer no such temperature constraint. In addition, there are many factors that make fuel gas easier to clean than gaseous of combustion. Coal gasification is very old technology. Before natural gas was introduced on the market, coal gasification was used to produce fuel gas for distribution in urban areas. It has also been used quite frequently in the chemical and petrochemical industries to produce raw material for chemical process. Converting coal into clean fuel gas offer a very attractive way of generating power. That is used gas and steam turbines, with minimum environment impact.

Hitachi started research on the entrained flow coal gasification process in 1980, developed the two-stage gasifier, and then researched the basic coal gasification technology of the gasifier using 1-t/d process development unit installed at Hitachi Researcher Laboratory in 1981.

The two-stage gasifier was adopted in 1986 as the coal gasification project of Japan sponsored by NEDO as a part of the Sunshine Project of MITI. Equipment development research was started using 3-t/d gasifier. HYCOL was established in 1986; it chose Hitachi's gasification process for its pilot plant. Hitachi group designed, fabricated, and constructed the 50t/d coal gasification pilot plant 1990[3].

The present paper addresses the continuation of that effort with the focus on the IGCC performance by using two-stage gasifier. This paper refers how to deal with molten slag and sticking fly ash, and show the effect on the total system performance on the focus decreasing of recycle gas.

PRINCIPLE OF THE TWO-STAGE GASIFICATION PROCESS

The principle of the two-stage gasification process is shown in Fig. 1. Features of the process are as follows.

(1) High gasification efficiency

Pulverized coal and oxygen, the gasification agent, are fed to upper and lower burners. They are tangentially installed on the gasifier in order to create a spiral flow in the gasifier. Enough oxygen is fed to the lower burners to melt down the ash contained in the feed coal. Pulverized coal fed to the upper burners is reacted at a lower temperature with a relatively smaller amount of oxygen, compared with that fed to the lower burner, and gasified and converted to reactive and less adhesive char. The char moves down along the spiral gas flow and mixes with high temperature gas in the lower portion of the gasifier, where gasification proceeds further. The produced gas is turned over and goes up to the exit of gasifier with a small amount of char.

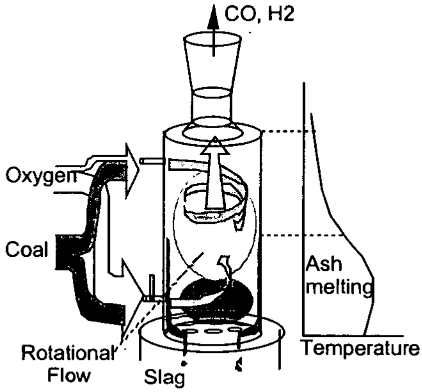

Fig. 1 Principle of the Two Stage Gasifier

(2) High thermal efficiency from a pneumatic feeding system

Pulverized coal is fed to the gasifier by a dense phase pneumatic feeding system using recycled gas or nitrogen. Therefore, a high temperature can be maintained with a small amount of oxygen, compared with the slurry feed system.

(3) Reliable gasifier with a slag self-coated water-cooled tube wall.

The gasifier consists of a water-cooled tube wall, which is lined by a newly developed high temperature resistant castable. Molten slag solidifies on the inside surface of the wall at first and then molten slag flows down over the surface of the solidified slag. The slag self-coated system is more reliable and extends operation time, compared with the refractory lined gasifier.

(4) Stable slag tapping

A pressure difference between the wall side and the center of the gasifier is generated by the spiral flow. Therefore, hot gas is recycled from slag taps to a gas tap. This ensures stable slagging of molten slag without burning auxiliary fuel.

For the purpose of estimation the two-stage gasification a computational fluids code has been developed for simulating coal gasifier.

REACTION MODEL

Coal gasification is modeled as simultaneous de-volatilization and char gasification processes. The coal volatile is assumed to be a hydrocarbon mixture containing all of the coal hydrogen with the remaining mass being carbon. The volatile evolve at a rate expressed in Arrhenius form:

$$\frac{dV}{dt} = A_v \exp\left(\frac{-E_v}{T_p}\right)(V - V_{max}) \qquad (1)$$

Where A_v and E_v are kinetic rate constants, V is the fraction of coal evolved as volatile, and V_{max} is the maximum volatile yield. Values of there parameters are shown in Table 1. Knill et al. (1989) showed that de-volatilization occurs during particle heating and is nearly instantaneous for particle temperature greater than 1300 K. Thus, the kinetic constants are chosen to ensure that de-volatilization is complete in 1 ms at 1300 K.

The remaining char is gasified with CO_2 and H_2O:

$$C + CO_2 \rightarrow 2CO \qquad (2)$$

$$C + H_2O \rightarrow CO + H_2 \qquad (3)$$

Both reactions are first order in the CO_2 and H_2O partial pressures, P_{CO_2} and P_{H_2O}, and they proceed in parallel. The chemical reaction rates are expressed in Arrhenius form:

$$k_{c,i} = A_{c,i} \exp\left(\frac{-E_{c,i}}{T}\right) \qquad (4)$$

Where the subscript i represents either c or h.

As the volatile is released from the coal, they react with oxygen to form complete combustion products.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O \qquad (5)$$

The volatile reaction rate, R_v, is controlled by the mixing of fuel and oxidant according to the Eddy Dissipation Model (EDM) of Magnussen and Hjertager (1976). In the EDM, reaction rate is defined as the product of a characteristic eddy lifetime, $k/\in$ and the minimum of the volatile and oxygen mass fractions, Y_v and Y_o, respectively:

$$R_v = A_{edm}\rho\frac{\in}{k}\min\left(Y_v, \frac{Y_o}{r_o}\right) \qquad (6)$$

Where r_o is the stoichiometry (mass O_2/mass volatile). The volatile combustion and char gasification products are redistributed in the gas phase aceording to these reactions:

$$CO_2 + H_2 \Leftrightarrow CO + H_2 \qquad (7)$$

$$C + 2H_2 \Leftrightarrow CH_4 \qquad (8)$$

The water/gas shift reaction and methane-steam reforming reaction may progress in either direction depending on gas composition and temperature as determined by equilibrium[4].

CALCULATION RESULTS

Calculation results shown by fig 2. Cold gas efficiency increased with increasing upper oxygen ratio to coal, and with increasing lower oxygen ratio. The peak value of cold gas efficiency is given when addition of upper oxygen ratio to coal and lower equal 0.9. That shows cold gas efficiency is decided by total oxygen ratio of gasifier.

The outer gas temperature increase with increasing total oxygen ratio. The lower region temperature increases with increasing only lower oxygen ratio to coal.

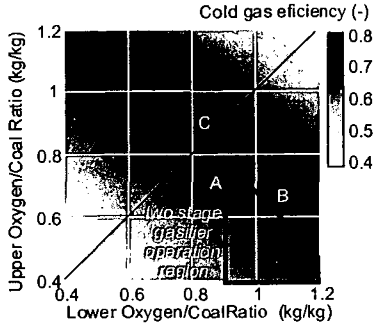

Fig. 2 Calculation Results of Two Stage Reaction

The operation region of oxygen ratio to coal at two-stage gasifier is described as below. To melt ash of coal, lower temperature need to be over ash melting point. Lower region of temperature is decided by lower oxygen ratio. Thus lower oxygen ratio need to be over the line A in figure 2.

On the other hand, the outer gas temperature is decided by total oxygen ratio. Total oxygen ratio need to be lower below the line B. Consequently operation region two-stage gasifier is shown as figure 2. The oxygen ratio to coal can be operated to be the maximum cold gas efficiency.

The oxygen coal ratio for the one stage gasifier depends on the temperature over than the melting point of coal. That is the oxygen feed operation need to be on the line C in figure 2. If the oxygen ratio to coal at the ash melting point is over than that given at the highest cold gas efficiency, the outer gas must increase. On the other hand the total oxygen ratio to coal does not have to be relate to the ash melting point at the two-stage gasifier. The two-stage gasifier can operate at lower oxygen concentration than one stage within some kinds of coal. Thus the two-stage gasifier can be operated in lower quench gas than the one stage gasifier.

EAGLE PLANT

The new 150 tons per day pilot plant has started construction from 1998 by Electric Power Development Co., LTD. EAGLE (Coal Energy Application for Gas Liquid and Electricity) project aims to increase efficiency of staged gasifer and to achieve high performance clean up system.

Figure 3 shows gasifier and heat exchanger at EAGLE Project.

The EAGLE system consists of an oxygen-blown entrained flow gasifier; dry type coal feed system and wet gas clean-up system. The heating value of the coal gas produced by the oxygen-blown gasifier is comparatively high, and the gas quantity produced by processing coal is partial produced by an air blown gasifier.

In addition, in the dry coal feed system, since the coal is transported by dry gas, the latent heat loss due to evaporation of water is nearly eliminated and the water content in the coal gas is kept to a minimum. As a result of the above, losses incurred during the process of wet gas clean-up i. e. sensible heat loss of the coal gas, H_2O and CO_2 losses are reduced. Therefore, a high heat efficiency system is expected[2].

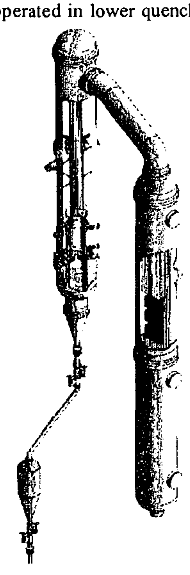

Fig3 Gasifier and Heat Exchanger

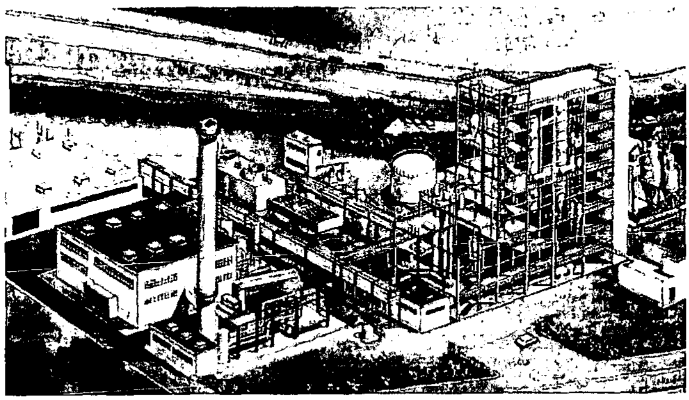

Fig4 Bird eye view of EAGLE Pilot Plant

CONCLUSIONS

This paper has described the present status of developments in the Power Plant as a part of the developments on coal usage technology. The technology strives to achieve the same aim as clean coal technology.

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